SYSTEM AND METHOD FOR FEATURE LOCATION AND TRACKING IN MULTIPLE DIMENSIONS INCLUDING DEPTH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001]   This application claims priority under 35 U.S.C. §119(e)(1) and 37 C.F.R. § 1.78(a)(4) to U.S. provisional application serial number 60/220,309, entitled SYSTEM AND METHOD FOR FEATURE LOCATION AND TRACKING IN MULTIPLE DIMENSIONS INCLUDING DEPTH and filed July 24, 2000; and claims priority under 35 U.S.C. § 120 and 37 C.F.R. § 1.78(a)(2) as a continuation-in-part to U.S. patent application serial number 09/206,195, entitled FACE RECOGNITION FROM VIDEO IMAGES and filed December 4, 1998. The entire disclosure of U.S. patent application serial number 09/206,195 is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002]   The present invention relates to feature tracking techniques, and more particularly, to an eye tracking technique that determines the location of a person's eyes in three-dimensional space.

[0003]   Virtual reality systems are able to generate three-dimensional images viewed by a person without special glasses using, for example, auto-stereoscopic imaging. Auto-stereoscopic imaging requires real time determination of a viewer's eyes in depth or in three dimensions.

[0004]   Accordingly, there exists a need for a system and related tools for location of a person's features in three-dimensional space. The present invention satisfies these needs.

SUMMARY OF THE INVENTION

[0005]   The present invention is directed to a method and related system for determining a feature location in multiple dimensions including depth. The method includes providing left and right camera images of the feature and locating the feature in the left camera image and in the right camera image using bunch graph matching. The feature location is determined in multiple dimensions including depth based on the feature locations in the left camera image and the right camera image.

[0006]   Other features and advantages of the present invention should be apparent from the following description of the preferred embodiments taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]   FIG. 1 is an elevation view of a face for feature tracking, according to the present invention.

[0008]   FIG. 2 is a plan view of the face of FIG. 1 with respect to two tracking cameras.

[0009]   FIG. 3 is a schematic diagram of the geometry of the face and tracking cameras of FIG. 2.

[00010]   FIG. 4A is an image from a left camera of the face of FIG. 1.

[00011]   FIG. 4B is an image from a right camera of the face of FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[00012]   The present invention is directed to a method and related system for determining a feature location in multiple dimensions including depth. The method includes providing left and right camera images of the feature and locating the feature in the left camera image and in the right camera image using bunch graph matching. The feature location is determined in multiple dimensions including depth based on the feature locations in the left camera image and the right camera image.

[00013]   An embodiment of the invention is described using a simple face image 12 is shown in FIG. 1. The left eye E of the face image is marked with a small diamond to indicate the left eye as a feature for tracking. For simplicity, tracking for only one feature is described. However, several features may be tracked by performing the analysis below for each feature.

[00014]   The location and tracking of the left eye may be accomplished using two cameras, a right camera CR and a left camera CL, as shown in FIG. 2. Two cameras are generally required for acquiring the location in multiple dimensions including depth using a simple geometrical model shown in FIG. 3. The coordinate system may be selected such that the cameras lie along an x-axis and the depth from the cameras is measured along a z-axis. The distance to the left eye E along the z-axis is a depth D and the distance along the x-axis is a length L (measured from the location of the right camera CR). A normal ray from each camera, NR and NL, indicates an image ray associated with an approximate center of the cameras imaging area.

[00015]   The imaging areas of the left and right cameras are shown in FIGS. 4A and 4B, respectively. Each imaging area is a rectangular array of imaging or picture elements (pixels). Each vertical row of pixels in each image area corresponds to a particular slope M for an image ray originating at an origin (based on a pinhole model) of the respective camera.

[00016]   The cameras may be calibrated for the image ray slope associated with each verticle row of pixels. A feature in the image frame may be located and tracked using elastic bunch graph matching. As shown in FIG. 4A, the left eye E is imaged in the left image along vertical pixel row PL and, as shown in FIG. 4B, the left eye E is imaged in the right image along vertical pixel row PR. The pixel rows PL and PR are associated with slopes ML and MR, respectively. Accordingly, the location of the left eye E is readily calculated in the x-z plane. Elastic bunch graph matching and more sophisticated geometrical models and calibration techniques are described in U.S. patent application number 09/206,195.

[00017]   In the elastic graph matching technique, an image is transformed into Gabor space using a wavelet transformations based on Gabor wavelets. The transformed image is represented by complex wavelet component values associated with each pixel of the original image.

[00018]   Although the foregoing discloses the preferred embodiments of the present invention, it is understood that those skilled in the art may make various changes to the preferred embodiments without departing form the scope of the invention. The invention is defined only by the following claims.

WE CLAIM: